Amer. Malac. Bull. **26**: 119-131 (2008)

Bivalve molluscs from the continental shelf of Jalisco and Colima, Mexican Central Pacific

Eduardo Ríos-Jara, Ernesto López-Uriarte, and Cristian M. Galván-Villa

Laboratorio de Ecosistemas Marinos y Acuicultura, Departamento de Ecología, Centro Universitario de Ciencias Biológicas y Agropecuarias, Universidad de Guadalajara, Carretera a Nogales km 15.5, Zapopan 40110, Jalisco, México, edurios@maiz.cucba.udg.mx, ernlopez@maiz.cucba.udg.mx

Abstract: A survey for bivalves was conducted at 25 sampling stations on the Mexican Central Pacific shelf off Jalisco and Colima, during the summer of 1988. The bivalves were sampled with a Van Veen grab at 16 stations with medium sand, sandy silt, and silty clay substrata at depths between 18 and 112 m. A total of 5,196 individuals belonging to 59 genera and 95 species of bivalves were found. A systematic list is provided with the relative abundance and density (individuals/m^2) for each species and information on depth, type of substratum, bottom water temperature, and oxygen concentration for each station. The twelve most common species (>100 individuals/station) in descending order of abundance were: *Nuculana laeviradius* (Pilsbry and Lowe, 1932), *Crassinella pacifica* (C. B. Adams, 1852), *Corbula nasuta* G. B. Sowerby I, 1833, *Anadara adamsi* Olsson, 1961, *Parvilucina approximata* (Dall, 1901), *Nucula declivis* Hinds, 1843, *Corbula ira* Dall, 1908, *Radiolucina cancellaris* (Philippi, 1846), *Cyclopecten pernomus* (Hertlein, 1935), *Nuculana lobula* (Dall, 1908), *Parvilucina mazatlanica* (Carpenter, 1857), and *Gouldia californica* Dall, 1917. The bathymetric patterns in the abundance and species composition of the bivalve community and their relationship to environmental parameters are discussed. The structure of the assemblages differed with depth, with peak abundances and species richness (1) between 24 and 40 m with medium sand and sandy silt substrata and (2) at intermediate depths between 71 and 74 m, with sandy silt and silty clay substrata. The species characterizing shallow, intermediate, and deep zones were the most abundant or those exclusive of each zone. Diversity, dominance, and evenness decreased at the deeper stations. The distinctive species composition of these zones may be the result of variation in depth, oxygen concentration, and substratum.

Key words: Bathymetric patterns, diversity, dominance, evenness, benthos

Our understanding of the taxonomic composition of the bivalve fauna of the Mexican Pacific stems from the exhaustive survey of Keen (1971) and the coverage of some Panamic taxa by Keen and Coan (1974) and Coan *et al.* (2000). The literature reviews of Skoglund (1991, 2001) are also important since they cite new species, redefine taxonomic relationships, and provide new records and range extensions for many bivalves from the Panamic Province.

Most of the ecological literature on benthic communities from the Mexican Pacific refers to the Gulf of California. Parker (1964) reviewed the early biological exploration in the Gulf of California and provided an extensive description of macroinvertebrate assemblages and their environments. Parker provided a list of more than 380 species of bivalves and assemblages from intertidal and shallow rocky or sandy shores to the abyssal basin and outer continental slope, to 4,122 m depth. Coan (1968) described the shallow benthic mollusc community (0-49 m) at Bahía de Los Angeles, located on the northeastern coast of Baja California, and concluded there was a single assemblage, typical of a silty-sand substratum in semi-protected bays of tropical and subtropical areas. Zamorano and Hendrickx (2007) reported a total of 56 species of deep-water molluscs collected during the TALUD IV-IX cruises in depths >500 m in the southern Gulf of California. The most recent biodiversity model of marine and brackish-water Mollusca from the Gulf of California, proposed by Hendrickx *et al.* (2007), analyzed the latitudinal and bathymetric distribution of 2,194 species, including 565 bivalves. Additionally, some catalogues of records of biological collections include bivalves from the Gulf of California (Morris 1966, Abbott 1974, Hendrickx and Toledano-Granados 1994, Hendrickx and Brusca 2002).

Surveys of mollusc communities from the Mexican Central Pacific are scarce, non-continuous, and have been carried out mostly in the intertidal and shallow subtidal zones. In the coast of Jalisco and Colima, only a few works focus mainly on the taxonomic composition and abundance of gastropods (Ríos-Jara *et al.* 1996, Pérez-Peña and Ríos-Jara 1998), scaphopods (Ríos-Jara *et al.* 2003a, 2003b), or both gastropod and bivalve communities (Landa-Jaime and Arciniega-Flores 1998, Ríos-Jara *et al.* 2001) with very few records of bivalves. Holguín-Quiñones and González-Pedraza (1994) provide the only catalogue of molluscs for this region and include 87 species of bivalves mostly from rocky and sandy beaches and shallow subtidal areas to 39 m depth.

The Atlas expeditions off the coast of Jalisco and Colima in 1988 resulted in one of the most important and most extensive collections to date of benthic marine molluscs from the Mexican Central Pacific. The R/V *El Puma* of the

Universidad Nacional Autónoma de México extensively sampled the shelf of both states, from Puerto Vallarta to the southern limit of Colima. The specimens were deposited in the collection of the Laboratorio de Ecosistemas Marinos y Acuicultura of the Universidad de Guadalajara in the city of Guadalajara and have resulted in reports mostly related to the gastropods and the scaphopods (Ríos-Jara *et al.* 1996, 2001, 2003a, 2003b, Pérez-Peña and Ríos-Jara 1998). The present study examines the bivalves collected during the Atlas V expedition along the continental shelf of Jalisco and Colima. Taxonomic changes are updated, and range extensions reviewed with an analysis of distribution patterns with respect to depth, oxygen concentration, and substratum.

MATERIALS AND METHODS

Study area

The area of study is the narrow (7-10 km) continental shelf off the states of Jalisco and Colima, along the Pacific coast of Mexico (Fig. 1) with an area of approx. 5, 315 km^2 (Ruíz-Durá 1985). The area extends *ca.* 364 km of coastline, from the mouth of the Río Ameca, Bahía Banderas (20°39′N), to the mouth of the Río Cohuayana (18°39′N).

This region has irregular topography, with foothills and mountains which form cliffs, bays, estuaries, and beaches of diverse sizes and shapes. *Ca.* 70% of the coastline is sandy beaches; rocky areas are mixed with sands and include volcanic rock platforms, boulders, stones, and pebbles. On the sea bottom, areas of uneven topography intercalate with relatively flat zones (Galavíz-Solís and Gutiérrez-Estrada 1978, Guzmán-Arroyo and Flores-Rosas 1988). The composition of sediments in the continental shelf of the tropical Mexican Pacific is mostly terrigenous and pelagic clays with small areas of calcareous and bio-siliceous mud and silts (McCoy and Sancetta 1985). This coastal region includes several rivers, coastal lagoons, and estuaries.

Sampling methods

On board the R/V *El Puma*, topography and depth were determined continuously with an Edowestern analog echo-

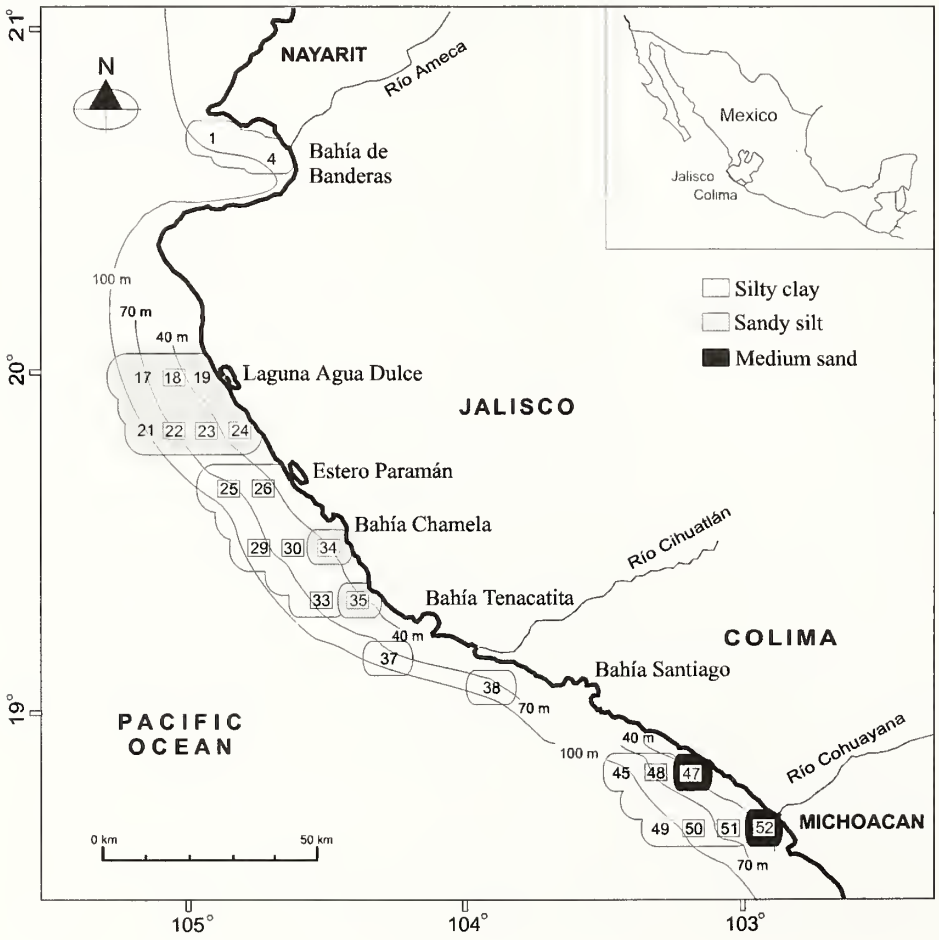

Figure 1. Location of sampling stations and types of substratum along the coast of Jalisco and Colima, Mexican Central Pacific. The stations with a square indicate those where bivalves were collected. The isolines at 40, 70, and 100 m indicate the shallow (18-40 m), intermediate (48-74 m), and deep (83-129 m) bathymetric zones in which sampling stations were grouped.

sounder system. Thirteen transects perpendicular to the coastline were established at intervals of ~10′ of latitude (Fig. 1). One to four sampling stations were conducted on each transect, for a total of 25 samples collected with a Van Veen grab. The grab collected 20 L of sediment in a surface area of 0.1 m^2. At each station, two grab samples were taken. The depth ranged from 18 to 129 m. Sediments were sieved through three screens (mesh size = 10, 3, and 1 mm) and analyzed in the Instituto de Geografía of the Universidad de Guadalajara, México.

Living bivalves were preserved in 70% ethanol. Individuals were identified to species using Morris (1966), Keen (1971), Abbott (1974), and Coan *et al.* (2000). Only shells that permitted clear identification were used. Taxonomy and distributional ranges were updated using Skoglund's publications (1991, 2001).

There are at least three types of substrata in the area (Pérez-Peña and Ríos-Jara 1998): (1) silty clay (most particles <0.02 mm), (2) sandy silt (0.02-0.015 mm), and (3) medium sand (>0.2 mm). Greater heterogeneity of the sediments occurred in shallow sampling stations (18-60 m) compared to the intermediate (48-74 m) and deeper stations. Sediments were more homogeneous at deeper stations than in the intermediate and shallow stations, and decreased in particle size from medium sand and sandy silt to silty clay.

To analyze the effect of depth and substratum on the distribution and abundance of the bivalves, sampling stations were grouped in (1) a shallow zone (SZ) (18-40 m) with coarse substratum (medium sand and sandy silt), which includes stations 52, 24, and 47; (2) a transition zone with intermediate depths (IZ) (48-74 m), sandy silt and silty clay, including stations 35, 23, 48, 26, 51, 34, 18, 22, and 30; and (3) a deep zone (DZ) (83-129 m) with homogeneous substratum made of silty clay, including stations 33, 50, 38, 25, 29, and 37.

Preliminary analysis revealed that abundance values were asymmetrical (X^2 goodness-of-fit statistic, $P < 0.01$), and sample variances were not homogeneous (Hartley's F_{max} test; Byrkit 1987) (Statgraphics plus 5.0 computer program). Therefore, the non-parametric Kruskal-Wallis test (Sokal and Rohlf 1989) was used to analyze bathymetric patterns of bivalve abundance. Significant differences were further analyzed using the Bonferroni test to identify differences of bivalve abundance means among sampling stations.

The structure of the bivalve community was analyzed by estimating ecological indices for the three bathymetric zones (SZ, IZ, and DZ) using the computer program Species Diversity and Richness III (1998). Diversity was estimated by means of the Shannon-Weaver index (H′) (Magurran 1988), species richness with the Margaleff Index (D_{Mg}) (Magurran 1988), dominance with the Simpson Index (D′) (Simpson 1949), and evenness with the Pielou Index (J′) (Pielou 1977). Differences in these indices among zones were determined with a Kruskal-Wallis test; significant differences were further analyzed using the *a posteriori* test of Bonferroni.

Pearson correlation coefficients (Minitab computer program; Sokal and Rohlf 1989) were used to determine the relationship between environmental (temperature, depth, and oxygen concentration) and biological parameters (abundance and number of species). The Pearson probability *P*-values were used to determine any significant correlations.

RESULTS

Composition and abundance

Bivalves were found at 16 of the 25 sampling stations, at depths between 18 and 112 m (Fig. 1). Most of these stations had silty clay (8 stations) and sandy silt (6 stations) substrata; only two stations had medium sand. A total of 5,196 individuals belonging to 28 families, 59 genera, and 95 species was collected (Appendix 1). The number of species per family varies considerably (from 1 to 15). Twelve families (42.85%) contain a single species, while the most diverse families contain nine or more species: Veneridae (15), Tellinidae (13), Lucinidae (10), and Arcidae (9).

The density of bivalves obtained with the grab ranged between 13,015 individuals /m^2 in station 47 and 15 individuals/m^2 in station 48 (mean density per station = 1,623.75). The number of species varied between 1 and 63 species/station (mean = 6) (Appendix 1). There was considerable variation in the structure of the bivalve communities along the continental shelf, with areas of high and low density of bivalves, and notable differences in the number and composition of species. In general, the zones with higher numbers of individuals coincide with those of high species richness (Fig. 2).

The density of individuals and species decrease at depths between 48 and 66 m of the Intermediate Zone (IZ) with 15-210 individuals/m^2 and 3-16 species/station, and in the Deep Zone (DZ) (83-112 m), with 55-2070 individuals/m^2 and only 1-11 species/station. Notably, the boundaries of these zones present areas with peaks of very high values: (1) in station 47 (40 m) between SZ and IZ, with total of 13,015 individuals/m^2 and 63 species and (2) in station 30 (74 m) between the IZ and DZ, with 5,585 individuals/m^2 and 28 species. These two areas include the majority of all bivalves collected (50.1% and 34.5% of all individuals, respectively) and a large fraction of the species (65.6% and 47.9%).

The assemblages of bivalve species across the continental shelf of Jalisco and Colima thus show a tendency to decrease in the abundance and number of species from the shallow to the deeper areas. However, there is not statistical

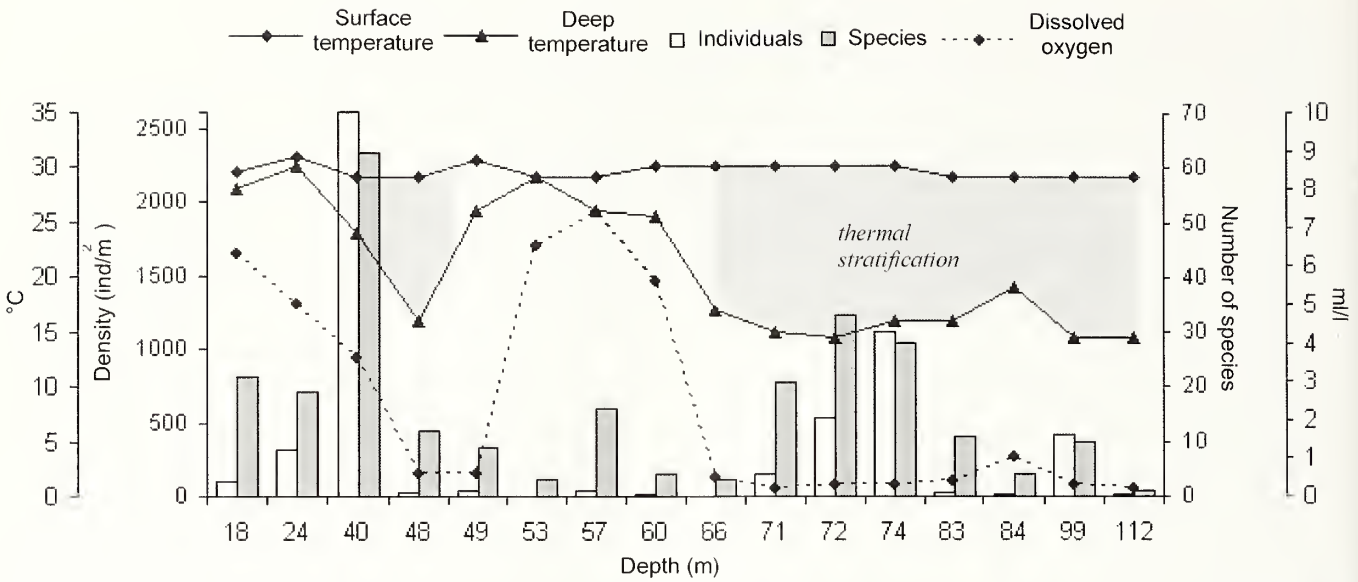

Figure 2. Density (individuals per m^2) and number of species collected with a Van Veen grab in the continental platform of Jalisco and Colima, México. The differences between surface and bottom temperatures during the sampling period define zones along the continental shelf with thermal stratification. Variation in dissolved oxygen concentration is also indicated.

difference in the abundance of bivalves between the bathymetric zones (Kruskal-Wallis test, $N = 3$, $P = 0.23$) (Table 3).

Relationship between environmental and biological parameters

Highly significant negative correlations occurred between depth and temperature (Pearson correlation, $r = -0.76$, $N = 16$, $P = 0.0003$) and depth and oxygen concentration ($r = -0.638$, $N = 16$, $P = 0.009$). Minimal values of temperature and oxygen occurred in areas deeper than 60 m although several peaks of both parameters are evident at depths of 18-24 m, 53-60 m, 84 m. Consequently, bottom water temperature was significantly correlated with oxygen concentration ($r = 0.874$, $N = 16$, $P = 0.00009$). Depth was significantly correlated with the number of species of bivalves ($r = -0.471$, $N = 16$, $P = 0.049$). Low oxygen concentrations overlap the areas of strong thermal stratification at 48 m and between 66 and 112 m depth. Oxygen levels increase considerably between 53 and 60 m where there is no apparent stratification. Continuous hypoxic conditions occur in areas deeper than 60 m but become more severe at station 29 where the oxygen level falls to 0.2 ml/l and only one species was collected (Fig. 2).

Because the peaks in the number of individuals and species closely coincide across the continental shelf (Fig. 2), both variables had a significant positive correlation coefficient ($r = 0.740$, $N = 16$, $P = 0.0005$). However, no significant correlation was found between depth and abundance ($r = -0.123$, $N = 16$, $P = 0.627$) probably because of the large increment in the number of bivalves registered in the station 25 at 99 m, especially the clams *Corbula ira* (242) and *Nuculana lobula* (149). The correlation coefficients for all other pairwise comparisons were low and not statistically significant ($P > 0.05$).

Twelve species were very common (>100 individuals) in the samples, representing 78.16% of all individuals (Table 1). These dominant species had a widespread bathymetric distribution across the continental shelf, but most individuals concentrated in high numbers in one or two stations either in the shallow (SZ) or deeper stations (DZ). This is more evident in the SZ, where nine dominant species represented 71% of the bivalve abundance and in the DZ where two species represent 91% of the abundance (Table 2). The observed decrease in the total bivalve density in the IZ is largely the result of the decline in the populations of the 12 most abundant species.

The shallow zone (18-40 m) contains an assemblage of 79 species. Eleven species are considered dominant (Table 2). These species are semi-infaunal or infaunal, which can be attributed to the sediment type, mostly medium sand (67%) and sandy silt (33%). The only epifaunal species in this group, *Cyclopecten pernomus*, was found in great numbers in medium sand substratum at 40 m. The family with the most species was Veneridae (3); each of the other eight dominant species belongs to different families. The stations with this assemblage of species are in Colima (52 and 47) and in the

Table 1. Abundance, habitat, and feeding habits of the most representative bivalve species. MS, medium sand; SS, sandy silt; SC, silty clay; DF, deposit feeder; FF, filter feeder.

Species	Abundance (total individuals)	Relative abundance (%)	Cumulative relative abundance (%)	Type of substratum	Depth range (m)	Habitat	Feeding habit
1. *Nuculana laeviradius*	690	13.28	13.28	MS, SS, SC	18-84	Infaunal	DF
2. *Crassinella pacifica*	680	13.09	26.37	MS, SS, SC	18-74	Infaunal	—
3. *Corbula nasuta*	535	10.30	36.66	MS, SS, SC	18-74	Infaunal	FF
4. *Anadara adamsi*	435	8.37	45.03	MS, SS, SC	24-94	Semi-infaunal	FF
5. *Parvilucina approximata*	399	7.68	52.71	MS, SS, SC	18-83	Infaunal	FF
6. *Nucula declivis*	263	5.06	57.78	MS, SS, SC	18-83	Infaunal	DF
7. *Corbula ira*	242	4.66	62.43	SC	99	Infaunal	—
8. *Radiolucina cancellaris*	208	4.00	66.44	MS, SS, SC	40-83	Infaunal	—
9. *Cyclopecten pernomus*	188	3.62	70.05	MS, SS, SC	24-74	Epifaunal	FF
10. *Nuculana lobula*	173	3.33	73.38	MS, SS, SC	18-112	Infaunal	DF
11. *Parvilucina mazatlanica*	144	2.77	76.15	MS, SS, SC	18-83	Infaunal	DF
12. *Gouldia californica*	104	2.00	78.16	MS, SS	40-72	Infaunal	FF

middle portion of Jalisco (24), but the assemblage possibly extends to all shallow areas with similar conditions along the length of the tropical Mexican Pacific. Many species (32) are found only in this zone, which indicates this is an optimum habitat for the bivalve species. The black clam *Megapitaria squalida* (G. B. Sowerby I, 1835) was the only dominant exclusive to this zone and together with other abundant species [*Corbula nasuta, Anadara adamsi, Cyclopecten pernomus, Gouldia californica, Chione compta* (Broderip, 1835), and *Semelina campbellorum* Coan, 2003] characterizes this assemblage (Table 2).

The intermediate zone assemblage (48-74 m) is distinct and is characterized by several species which are dominant only in this zone: *Parvilucina approximata, Parvilucina mazatlanica, Lucinisca centrifuga* (Dall, 1901), and *Nuculana acapulcensis* (Pilsbry and Lowe, 1932) (Table 2). The family with the most dominant species (4) was Lucinidae followed by Nuculanidae (2). The zone has finer sediments than the SZ (mostly sandy silt and silty clay), and most of the dominant species are also semi-infaunal or infaunal. Although five dominant species were also dominant in the shallow zone, there is also a considerable number of exclusive species (10). Some of these species were also found in deeper waters, until 83 m. The total number of species (55) and individuals (1,896) decrease with respect to shallower areas although both species and individuals are considerably higher between 71 and 74 m.

All samples from stations in the outer shelf, 83 to 112 meters, were taken on silty clay bottom. This deeper zone contained a rather different assemblage of bivalve species from those found in the shallow and intermediate zones. This was the zone with the lowest number of bivalve species (22) although three were exclusive to this zone. Although only two species, *Nuculana lobula* and *Corbula ira*, may be considered dominant because of their high relative abundance, it is notable that *C. ira* is also exclusive to this zone.

Species richness, diversity, dominance, and evenness

The shallow and intermediate zones have similar values for the ecological indices, but they all decrease toward the deep zone. However, significant differences were found only in species richness and diversity among the bathymetric zones (Kruskal-Wallis test, $N = 3$, $P < 0.05$) (Table 3). The Bonferroni multiple-comparison test revealed that the values for the SZ and IZ were not statistically different but both were greater than in the DZ.

DISCUSSION

Although bivalves play a key role in the macroinvertebrate community of the intertidal zone, there have been few attempts to relate benthic bivalves to environmental factors in the continental shelf of Jalisco and Colima. Trawling nets used in other studies do not collect the smaller semi-infaunal and infaunal species which comprise this group (Landa-Jaime and Arciniega-Flores 1998, Godínez-Dominguez and Gonzalez-Sanson 1999). These studies thus underestimate their importance in the benthos. During the Atlas V expedition, the fauna from grab samples included many gastropods (Perez-Peña 1989) and some scaphopods (Ríos-Jara *et al.* 2003a) but bivalves represented the greatest numbers of individuals and species.

Because most species were found in more than one bathymetric zone, specific assemblages were characterized by the dominant species and by those found in only one zone.

Table 2. Most abundant and exclusive species in the shallow, intermediate, and deep zones. The most abundant species of each list contain ≥80% of all individuals within each zone.

Shallow zone 18-40 m 67% medium sand, 33% sandy silt	Intermediate zone 41-80 m 56% sandy silt, 44% silty clay	Deep zone 81-129 m 100% silty clay
Most abundant species		
1. *Corbula nasuta*	1. *Parvilucina aproximata*	1. *Corbula ira*
2. *Nuculana laeviradius*	2. *Crassinella pacifica*	2. *Nuculana lobula*
3. *Anadara adamsi*	3. *Nuculana laeviradius*	
4. *Crassinella pacifica*	4. *Radiolucina cancellaris*	
5. *Nucula declivis*	5. *Parvilucina mazatlanica*	
6. *Cyclopecten pernomus*	6. *Lucinisca centrifuga*	
7. *Megapitaria squalida*	7. *Nuculana acapulcensis*	
8. *Gouldia californica*	8. *Nucula declivis*	
9. *Chione compta*	9. *Cyclopecten pernomus*	
10. *Radiolucina cancellaris*		
11. *Semelina campbellorum*		
Exclusive species		
1. *Anadara aequatorialis*	1. *Anadara obesa*	1. *Corbula ira*
2. *Anadara nux*	2. *Barbatia reeveana*	2. *Kellia suborbicularis*
3. *Chione pulicaria*	3. *Conchocele excavata*	3. *Strophocardia megastropha*
4. *Corbula marmorata*	4. *Crassinella varians*	
5. *Crassinella ecuadoriana*	5. *Lucinisca fenestrata*	
6. *Donax gracilis*	6. *Macoma siliqua*	
7. *Dosinia dunkeri*	7. *Nucula schenki*	
8. *Isognomon recognitus*	8. *Pitar aletes*	
9. *Laevicardium elenense*	9. *Pitar berryi*	
10. *Lirophora mariae*	10. *Tellina pristiphora*	
11. *Lucina prolongata*		
12. *Lunarca brevifrons*		
13. *Mactrellona subalata*		
14. *Megapitaria squalida*		
15. *Lirophora kellettii*		
16. *Pitar concinnus*		
17. *Plicatula pencillata*		
18. *Psammotreta aurora*		
19. *Semele pallida*		
20. *Semele verrucosa*		
21. *Sheldonella olssoni*		
22. *Strigilla cicercula*		
23. *Strigilla dichotoma*		
24. *Strigilla sp.*		
25. *Tagelus politus*		
26. *Tellina pacifica*		
27. *Trachycardium belcheri*		
28. *Trachycardium procerum*		
29. *Trachycardium senticosum*		
30. *Transennella modesta*		
31. *Trigoniocardia granifera*		

Considerable changes in species composition and dominance occur because the most abundant species were frequently collected in high numbers (>100 individuals) but only at one or two sampling stations. Species with a wide bathymetric distribution tend to be found either in the shallow or the deep zone, forming aggregations at specific sampling stations. In addition, even though bivalve abundance can be highly variable, some predictions of community structure can be made based on a few key environmental factors such as type of substratum and oxygen concentration.

Thorson (1957) proposed that parallel bottom communities, characterized by closely related genera, exist where environmental conditions are similar. Parker (1964) found similar species assemblages, including bivalves, in areas with similar conditions, as predicted by Thorson (1957). Other examples of parallel communities have also been described (*e.g.*, Coull and Herman 1970, Asakura and Suzuki 1987, Chertoprud *et al.* 2007). However, there are also examples that do not support the parallel communities hypothesis (Gallardo 2003). A comparison of the bivalve assemblage described by Parker (1964) from nearshore (11-26 m) with sand to sand-mud substrata of the Gulf of California to the bivalve assemblage of the shallow-water zone (18-40 m) with medium sand and sandy silt of Jalisco and Colima indicates some similarities. In both regions, the majority of species live in semi-infaunal and infaunal habitats, and the most diverse families are Nuculanidae and Veneridae. In addition, *Megapitaria squalida* is very abundant, several species of the genera *Nuculana* Link, 1807, *Anadara* J. E. Gray, 1847 and *Chione* Megerle von Mühlfeld, 1811 are dominant in both assemblages, and both share the same three most diverse families (Veneridae, Tellinidae, and Arcidae) (Hendrickx *et al.* 2007). Other comparisons among

Table 3. Ecological indices estimated for the bivalve communities from three bathymetric zones of the continental shelf of Jalisco and Colima, México. H′ = Shannon-Weaver's diversity index, D_{Mg} = Margaleff's species richness index, D′ = Simpson's dominance index and J′ = Pielou's evenness index. Significant differences among zones (*) were found for the Species richness (D_{Mg}) and Diversity (H′) indices (Kruskal-Wallis Test, $P < 0.05$) and were further analyzed using the Bonferroni test.

	Shallow zone (SZ)	Intermediate zone (IZ)	Deep zone (DZ)	Kruskal-Wallis test (H value)	Bonferroni test among zones
Total number of individuals (N)	2834	1896	466	2.41	
Total number of species (S)	79	55	22		
Species richness (D_{Mg})	9.81	7.15	3.41	6.81*	SZ = IZ > DZ
Diversity (H′)	2.86	2.63	1.32	6.58*	SZ = IZ > DZ
Dominance (D′)	10.28	8.91	2.54	4.16	
Evenness (J′)	0.62	0.57	0.28	1.61	

the bivalve assemblages of Jalisco and Colima and those described by Parker (1964) show fewer similarities. The physical characteristics of these environments and the biology of the species provide explanations for the presence of distinct bivalve assemblages in the different zones across the continental shelf of Jalisco and Colima. A reduction in macrofaunal diversity with depth was also observed in the molluscs from the Gulf of California (Hendrickx *et al.* 2007). Other studies, however, showed no significant relationship between diversity and depth for the demersal invertebrate communities of the southern continental shelf of Jalisco (Landa-Jaime and Arciniega-Flores 1998, Godinez-Dominguez and Gonzalez-Sanson 1999).

The abundance of bivalves depends on their affinity to type of substratum, temperature, depth, and oxygen concentration (Levin *et al.* 2001). The structure and composition of soft-sediment communities are related to sediment characteristics (*e.g.*, Sanders 1968, Gray 1981, Snelgrove and Butman 1994); the type of substratum is particularly important since all these species live on or within the sediments. However, the presence of some species or even the whole assemblages may also be determined indirectly by biological factors, such as feeding mechanisms, competition for food, predator-prey relationships, etc. In the present study, the abundance and distribution of bivalves was related to the type of substratum and feeding habit. Some of the most abundant species, such as the infaunal, filter feeding *Corbula ira*, *Nuculana lobula*, and *Parvilucina approximata* were more common in finer substrata, while some semi-infaunal (*Anadara adamsi*) and epifaunal (*Cyclopecten pernomus*) filter feeding species were characteristic of coarser substrata. In general, filter feeding was important for most of the bivalve species, and was more common in shallow epibenthic and semi-infaunal habitats.

In the continental shelf of the tropical Mexican Pacific, the irregular topography of the coastline is closely related to the different substrata, predominantly of terrigenous origin, found in this region (McCoy and Sancetta 1985). The spatial variation in species diversity is correlated with the heterogeneity of sediment grain size across the continental shelf. The greater heterogeneity in particle size and texture of the shallow areas probably offers a greater variety of benthic habitats. Species composition across the continental shelf was closely related to the vertical distribution of the sediments. Most bivalves were collected in the sandy silt and silty clay substrata of the shallow zone (18-40 m). The majority of these species are filter feeders or deposit feeders that rely on the infaunal or semi-infaunal habitats of the sea floor. Some other representative species of this zone are epifaunal filter feeders including those of the families Arcidae, Chamidae, Mytilidae, Pectinidae, and Plicatulidae. Among the most important are the ark shell *Arca pacifica* (G. B. Sowerby I, 1833), the so called "pata de mula" *Anadara* spp., the Pacific chama *Chama sordida* Broderip, 1835, the scallop *Argopecten ventricosus* (G. B. Sowerby II, 1842) and the mother-of-pearl *Pteria sterna* (Gould, 1851). These species live attached to hard substrata, other shells, rocks, or even fixed by the left valve (*C. sordida*).

In the intermediate and deep zones, sediments are finer and more homogeneous than in the shallow zone and the number of species decreases. The number of epifaunal species also decreases, and most are infaunal deposit or filter feeders, with a single semi-infaunal species of carrion feeder (Verticoriidae). In the deep zone, the number of species is even lower and dominance increases because two infaunal species, *Corbula ira* and *Nuculana lobula*, represent 31% of all individuals in this zone.

Bottom water temperatures apparently had little effect on the abundance and distribution of bivalves; the sampling stations with the greatest abundance had temperatures within a wide range of values. However, the differences between surface and bottom water temperatures are probably important because thermal stratification may control oxygen and food supply from surface waters. Benthic biomass and abundance are assumed to reflect the rate of nutrient input to the seafloor. Other variables related to thermal stratifica-

tion are the hydrodynamic regime and the water circulation. Bottom water oxygen concentrations in the continental shelf of the Mexican Tropical Pacific vary from high values (~5 ml/l) in the shallow areas <100 m when the circulation is strong enough to maintain high concentrations or little oxygen consumption in the bottom layer, to low values (0.25 ml/l) toward deeper areas where there is weak circulation (Pacheco-Sandoval 1991). In the area of study, prolonged periods of hypoxic conditions may eliminate most macrobenthos from the seabed (they either emigrate from the area or die). A hypoxia-stressed benthos is typified by short-lived, smaller surface deposit-feeding polychaetes and the absence of bivalves (Rabalais *et al.* 2002). Thus, peaks in bivalve abundance occur in the areas of strong stratification where the availability of dissolved oxygen probably is not a limiting factor.

In the eastern Pacific Ocean there are extensive midwater regions where oxygen is depleted, typically between 100 and 1,200 m depth (Oxygen Minimum Zone, OMZ) (Kamykowsky and Zentara 1990, Levin *et al.* 2001). In shallow areas, OMZ may be evident at depths lower than 100 m. Where these low oxygen regions intercept the continental seabed, the benthos experiences hypoxia (Gallardo 1985, Levin *et al.* 1991) and reduced macrofaunal diversity (Parker 1964, Mullins *et al.* 1985, Levin *et al.* 1991). Our data for the continental shelf of Jalisco and Colima coincide with this general pattern.

Although oxygen exerts a strong effect on species richness, organic matter has a greater influence on dominance (Levin and Cage 1998). Together these factors lower diversity within the OMZs. Significant reduction of macrofaunal species richness by low oxygen may not occur until concentrations fall below 0.4 or 0.3 ml/l; this value may be ever lower for those species tolerant to hypoxia (Levin *et al.* 2001). Among the macrofauna, many molluscs appear less tolerant of hypoxia than other taxa (Diaz and Rosenberg 1995) although there are some exceptions. In the continental shelf of Jalisco and Colima, the number of species decreases in the deep zone where oxygen concentrations fall to ≤0.3 ml/l. However, such species as *Corbula ira* and *Nuculana lobula* are very abundant and cause an overall decrease in diversity. Members of the family Lucinidae seem particularly widespread at this zone. The affinity of lucinid bivalves to numerous OMZ sites within the eastern Pacific has been documented by Levin *et al.* (2001).

In summary, the results suggest that substratum variability, oxygen concentration, and thermal stratification have an important influence on the bathymetric distribution and abundance of bivalves in the continental shelf of Jalisco and Colima, and that the bivalve assemblages are not simply the result of species independently sorting in diverse environments. This study also shows that, even under hypoxic conditions, bivalves may display significant peaks of abundance. During the Atlas V expedition the abundance and the number of species of gastropods and scaphopods also decreased with depth and no live specimens were collected at stations deeper than 83 m (Perez-Peña and Ríos-Jara 1998, Ríos-Jara *et al.* 2003b). Low dissolved oxygen concentrations have also been mentioned as limiting the distribution of benthic molluscs from the Gulf of California (Guerrero-Pelcastre 1986) and the continental platform of Guerrero (Lesser-Hiriart 1984). In the present study, the dominant species were used to characterize the bathymetric zones; however, the importance of many less common or even rare species should also be taken into consideration because they determine the structure of the community.

ACKNOWLEDGMENTS

The oceanographic expedition Atlas V on board of the R/V *El Puma* was conducted with the technical and financial support of the Universidad de Guadalajara (UdeG) and the Universidad Nacional Autónoma de México under the supervision of Manuel Guzmán Arroyo. All persons in the Laboratorio de Ecología Marina at the former Facultad de Ciencias, Universidad de Guadalajara (UdeG) offered us much help during field and laboratory work, especially Martín Pérez Peña, Lucía Lizárraga, and Samuel Rentería. David Barrera (Instituto de Geografía, UdeG) made the determinations of the types of substrata found in the area of study. The authors are grateful to Eugene V. Coan for his critical review of the manuscript and help with the taxonomic identification and validation of the bivalves. Paul Valentich Scott of the Invertebrate Zoology Department at the Santa Barbara Museum of Natural History also validated some species. Kirstie Kaiser kindly gave us access to her mollusc collection during the taxonomic revision of the species in Puerto Vallarta.

LITERATURE CITED

Abbott, R. T. 1974. *American Seashells.* Van Nostrand Reinhold Co., New York.

Asakura, A. and H. Suzuki. 1987. Zoogeographical aspects of rocky-intertidal molluscan fauna of the Pacific coasts of Japan. *Marine Biology* **95**: 75-81.

Byrkit, D. 1987. *Statistics Today: A Comprehensive Introduction.* Benjamin Cummings Publishing, Menlo Park, California.

Chertoprud, E. S., M. V. Chertoprud, L. A. Garlitskaya, A. I. Azovsky, and D. V. Kondar. 2007. Spatial variability of the structure of the Harpacticoida (Copepoda) crustacean assem-

blages in intertidal and shallow-water zones of European seas. *Oceanology* **47**: 51-59.

Coan, E. V. 1968. A biological survey of Bahia de Los Angeles, Gulf of California, Mexico. III. Benthic Mollusca. *Transactions of the San Diego Society of Natural History* **15**: 107-132.

Coan, E. V., P. V. Scott, and F. R. Bernard. 2000. *Bivalve Seashells of Western North America. Marine Mollusks from Arctic Alaska to Baja California.* Santa Barbara Museum of Natural History Monographs, Santa Barbara.

Coull, B. C. and S. S. Herman. 1970. Zoogeography and parallel level-bottom communities of the meiobenthic harpacticoida (Crustacea, Copepoda) of Bermuda. *Oecologia* **5**: 392-399.

Diaz, R. J. and R. Rosenberg. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: An Annual Review* **33**: 245-303.

Galaviz-Solís, A. and M. Gutiérrez-Estrada. 1978. Características costeras y litorales de Nayarit y norte de Jalisco, México. *Memorias del VI Congreso Nacional de Oceanografía. Ensenada, Baja California, México.* Pp. 46-54 [In Spanish].

Gallardo, V. A. 1985. Efectos del fenómeno de El Niño sobre el bentos sublitoral frente a Concepción, Chile. *In*: W. Arntz, A. Landa, and J. Tarazona, ed., *El Niño y su impacto en la fauna marina*, Instituto del Mar del Perú, Lima Peru, Bol. Extraordin. Pp. 79-85 [In Spanish].

Gallardo, V. A. 2003. The impact of Scripps' NAGA Expedition on Thorson's parallel animal community hypothesis. *Oceans Proceedings* **5**: 1-23.

Godínez-Domínguez, E. and G. González-Sansón. 1999. Diversity of soft-bottom macroinvertebrates from the continental shelf off Jalisco and Colima, Mexico. *Ciencias Marinas* **25**: 609-627.

Gray, J. S. 1981. *The Ecology of Marine Sediments.* Cambridge University Press, Cambridge, UK.

Guerrero-Pelcastre, V. M. 1986. *Sistemática y ecología de los moluscos bentónicos del Golfo de California.* Escuela Nacional de Estudios Profesionales, Universidad Nacional Autónoma de México, México [In Spanish].

Guzmán-Arroyo, M. and E. Flores-Rosas. 1988. *Campaña oceanográfica "Atlas V" Jalisco-Colima.* Informe de actividades del Instituto de Limnología, Universidad de Guadalajara, Guadalajara, México [In Spanish].

Hendrickx, M. E. and R. C. Brusca. 2002. Mollusca. *In*: M. E. Hendrickx, and R. C. Brusca, eds., *Distributional Checklist of the Macrofauna of the Gulf of California, México.* Arizona-Sonora Desert Museum, Tucson, Arizona. Pp. 159-273

Hendrickx, M. E. and A. Toledano-Granados. 1994. *Catálogo de moluscos. Colección de referencia de la estación Mazatlán, ICMyL, UNAM.* Comisión Nacional para el Conocimiento y Uso de la Biodiversidad e Instituto de Ciencias del Mar y Limnología. Universidad Nacional Autónoma de México, México [In Spanish].

Hendrickx, M. E., R. C. Brusca, M. Cordero, and G. Ramirez. 2007. Marine and brackish-water molluscan biodiversity in the Gulf of California, Mexico. *Scientia Marina* **71**: 637-647.

Holguín Quiñones, O. E. and A. C. González Pedraza. 1994. *Moluscos de la franja costera de Michoacán, Colima y Jalisco, México.* Instituto Politécnico Nacional, México, D.F. [In Spanish].

Kamykowski, D. and S. J. Zentara. 1990. Hypoxia in the world ocean as recorded in the historical data set. *Deep-Sea Research* **37**: 1861-74.

Keen, M. A. 1971. *Sea Shells of Tropical West America.* Stanford University Press, Stanford.

Keen, M. A. and E. Coan. 1974. *Marine Molluscan Genera of Western North America.* Stanford University Press, Stanford.

Landa-Jaime, V. and J. Arciniega-Flores. 1998. Soft-bottom benthic macro-mollusks of the continental shelf off Jalisco and Colima, Mexico. *Ciencias Marinas* **24**: 155-167.

Lesser-Hiriart, H. 1984. *Prospección sistemática y ecológica de los moluscos bentónicos de la plataforma continental del estado de Guerrero, México.* Facultad de Ciencias, UNAM, México, D.F. [In Spanish].

Levin, L. A. and J. D. Cage. 1998. Relationships between oxygen, organic matter and the diversity of bathyal macrofauna. *Deep-Sea Research* **45**: 129-163.

Levin, L. A., C. L. Huggett, and K. F. Wishner. 1991. Control of deep-sea benthic community structure by oxygen and organic-matter gradients in the eastern Pacific Ocean. *Journal of Marine Research* **49**: 763-800.

Levin, L. A., R. J. Etter, M. A. Rex, A. J. Gooday, C. R. Smith, J. Pineda, C. T. Stuart, R. R. Hessler, and D. Pawson. 2001. Environmental influences on regional deep-sea species diversity. *Annual Review of Ecology and Systematics* **32**: 51-93.

Magurran, A. E. 1988. *Ecological Diversity and its Measurement.* Princeton University Press, Princeton, New Jersey.

McCoy, F. and C. Sancetta. 1985. North Pacific sediments. *In*: E. A. Naim, F. G. Stehli, and S. Uyeda, eds., *Ocean Basins and Margins: The Pacific Ocean.* Plenum Press. New York.

Morris, P. A. 1966. *A Field Guide to Shells of the Pacific Coast and Hawai.* Houghton Mifflin, Boston.

Mullins, H. T., J. B. Thompson, K. McDougall, and T. L. Vercoutere. 1985. Oxygen-minimum zone edge effects, evidence from the central California coastal upwelling system. *Geology* **13**: 491-494.

Pacheco-Sandoval, P. 1991. Pacífico tropical mexicano. Cabo Corrientes a la frontera con Guatemala. Oceanografía quimica. *In*: G. De La Lanza-Espino, ed., *Oceanografía de los Mares Mexicanos.* AGT Editor, México. Pp. 177-207 [In Spanish].

Parker, R. H. 1964. Zoogeography and ecology of some macroinvertebrates, particularly mollusks, in the Gulf of California and the continental slope off Mexico. *Dansk Naturhistorisk Forening, Videnskabelige Meddelelser* **126**: 1-178.

Pérez-Peña, M. 1989. *Moluscos gasterópodos de la campaña oceanográfica Atlas V: Plataforma continental Jalisco-Colima, México.* Facultad de Ciencias, Universidad de Guadalajara [In Spanish].

Pérez-Peña, M. and E. Rios-Jara. 1998. Gastropod mollusks from the continental shelf off Jalisco and Colima, México: Species collected with a trawling net. *Ciencias Marinas* **24**: 425-442.

Pielou, E. C. 1977. *Mathematical Ecology.* John Wiley, New York.

Rabalais, N. N., R. E. Turner, and W. J. Wiseman. 2002. Gulf of

Mexico hypoxia, Aka "The Dead Zone". *Annual Review of Ecology and Systematics* **33**: 235-263.

Ríos-Jara, E., M. Pérez-Peña, L. Lizárraga-Chávez, and J. E. Michel-Morfín. 1996. Additional gastropod records from the continental shelf off Jalisco and Colima, Mexico. *Ciencias Marinas* **22**: 347-359.

Ríos-Jara, E., M. Pérez-Peña, R. Beas-Luna, E. López-Uriarte, and E. Juárez-Carrillo. 2001. Gastropods and bivalves of commercial interest from the continental shelf of Jalisco and Colima, México. *Revista de Biología Tropical* **49**: 785-789.

Ríos-Jara, E., E. López-Uriarte, M. Pérez-Peña, and E. Juárez-Carrillo. 2003a. Nuevos registros de escafópodos para la costa de Jalisco y Colima, México. *Hidrobiología* **13**: 167-170 [In Spanish].

Ríos-Jara, E., M. Pérez-Peña, E. López-Uriarte, and E. Juárez-Carrillo. 2003b. Scaphopod mollusks from the Atlas V expedition (Continental shelf of Jalisco and Colima, México) on board of the R/V "El Puma". *Ciencias Marinas* **29**: 67-76.

Ruíz-Durá, M. F. 1985. *Recursos pesqueros de las costas de México.* Limusa, D.F., México [In Spanish].

Sanders, H. L. 1968. Marine benthic diversity: A comparative study. *American Naturalist* **102**: 243-282.

Simpson, E. H. 1949. Measurement of diversity. *Nature* **163**: 688.

Skoglund, C. 1991. Additions to the Panamic province bivalve (Mollusca) literature 1971-1990. *The Festivus* **22**: 1-74

Skoglund, C. 2001. Panamic province molluscan literature: Additions and changes from 1971 through 2000. I. Bivalvia II. Polyplacophora. *The Festivus* **33**: 1-140.

Snelgrove, P. V. and C. A. Butman. 1994. Animal-sediment relationships revisited: Cause vs. effect. *Annual Review of Oceanography and Marine Biology* **32**: 111-177.

Sokal, R. R. and F. J. Rohlf. 1989. *Biometry*. W. H. Freeman, San Francisco.

Species Diversity and Richness III. 1998. Pisces Conservation Ltd. IRC House, Pennington, Lymington, U.K.

Thorson, G. 1957. Bottom communities (sublittoral or shallow shelf). *In*: J. W. Hedgpeth, ed., *Treatise on Marine Ecology and Paleoecology*, Vol I. *Geological Society of America Memoires* **67**: 461-534.

Zamorano, P. and M. E. Hendrickx. 2007. Biocenosis y distribución de los moluscos de aguas profundas en el Pacífico mexicano: una evaluación de los avances. *In*: E. Ríos-Jara, M. C. Esqueda-González, and C. M. Galván-Villa, eds., *Estudios sobre la malacología y conquiliología en México*, Universidad de Guadalajara, Jalisco, México. Pp 48-49 [In Spanish].

Submitted: 21 June 2007; **accepted:** 24 June 2008; **final revisions received:** 4 November 2008

Appendix 1. Density (individuals/m^2) of bivalve species obtained with a Van Veen grab in the continental platform of Jalisco and Colima, México. MS, medium sand; SS, sandy silt; SC, silty clay.

Sampling station	52	24	47	35	23	48	26	51	34	18	22	30	33	50	25	29	
Type of substratum	MS	SS	MS	SS	SS	SC	SC	SC	SS	SS	SS	SC	SC	SC	SC	SC	Mean
Depth (m)	18	24	40	48	49	53	57	60	66	71	72	74	83	84	99	112	number of
Temperature (°C)	28	30	24	16	26	29	26	25.5	17	15	14.5	16	16	19	14.5	14.5	individuals
Dissolved oxygen (ml/l)	6.3	5.0	3.6	0.6	0.6	6.5	7.4	5.6	0.5	0.2	0.3	0.3	0.4	1.0	0.3	0.2	per m^2
Family Nuculidae																	
1. *Nucula declivis* Hinds, 1843	25		895	45	5		5			5	215	115	5				82.18
2. *Nucula schenki* Hertlein and Strong, 1940				5	5						80	10					6.25
Family Nuculanidae																	
3. *Nuculana acapulcensis* (Pilsbry and Lowe, 1932)	5			5	65		20		5	85	125	110	5				26.56
4. *Nuculana laeviradius* (Pilsbry and Lowe, 1932)	50	15	2235	5		5		10		25	155	940	5	5			215.62
5. *Nuculana lobula* (Dall, 1908)	5									35	10		15		745	55	50.06
Family Arcidae																	
6. *Acar gradata* (Broderip and G. B. Sowerby I, 1829)		5			5												0.625
7. *Anadara adamsi* Olsson, 1961		5	1900		90						85	95					135.93
8. *Anadara aequatorialis* (d'Orbigny, 1846)			30														1.87
9. *Anadara concinna* (G. B. Sowerby I, 1833)			110							5	5						7.5
10. *Anadara formosa* (G. B. Sowerby I, 1833)			5														0.31
11. *Anadara obesa* (G. B. Sowerby I, 1833)												40					2.5
12. *Arca pacifica* (G. B. Sowerby I, 1833)		5													10		0.94
13. *Barbatia reeveana* (d'Orbigny, 1846)							5										0.31
14. *Lunarca brevifrons* (G. B. Sowerby I, 1833)			5														0.31
Family Noetiidae																	
15. *Sheldonella delgada* (Lowe, 1935)			35		5						10	50	5		5		6.56
16. *Sheldonella olssoni* (Sheldon and Marry, 1922)		30															1.87
Family Glycymerididae																	
17. *Tucetona multicostata* (G. B. Sowerby I, 1833)		5													15		1.25
18. *Tucetona strigilata* (G. B. Sowerby I, 1833)		5	15								5						1.56
Family Mytilidae																	
19. *Crenella decussata* (Montagu, 1808)			225								10	45					18.44
Family Pteriidae																	
20. *Pteria sterna* (Gould, 1851)			10														0.625
Family Isognomonidae																	
21. *Isognomon recognitus* (Mabille, 1895)		90															5.625
Family Pectinidae																	
22. *Argopecten ventricosus* (G. B. Sowerby II, 1842)			105		5		5				5				5		7.812
23. *Leptopecten biolleyi* (Hertlein and Strong, 1946)			20								10	20					3.125
24. *Leptopecten velero* (Hertlein, 1935)		5	20									5					1.875
Family Propeammusiidae																	
25. *Cyclopecten pernomus* (Hertlein, 1935)		5	565		20						90	260					58.75
Family Plicatulidae																	
26. *Plicatula pencillata* Carpenter, 1857	5	35	25														4.06
Family Crassatellidae																	
27. *Crassinella adamsi* Olsson, 1961			30				5				5						2.5
28. *Crassinella ecuadoriana* Olsson, 1961		10															0.625
29. *Crassinella pacifica* (C. B. Adams, 1852)	45		1505	5			10				625	1180	15				212.5
30. *Crassinella varians* (Carpenter, 1857)												15					0.94

Appendix 1. (continued)

Sampling station	52	24	47	35	23	48	26	51	34	18	22	30	33	50	25	29	
Type of substratum	MS	SS	MS	SS	SS	SC	SC	SC	SS	SS	SS	SC	SC	SC	SC	SC	Mean
Depth (m)	18	24	40	48	49	53	57	60	66	71	72	74	83	84	99	112	number of
Temperature (°C)	28	30	24	16	26	29	26	25.5	17	15	14.5	16	16	19	14.5	14.5	individuals
Dissolved oxygen (ml/l)	6.3	5.0	3.6	0.6	0.6	6.5	7.4	5.6	0.5	0.2	0.3	0.3	0.4	1.0	0.3	0.2	per m^2
Family Carditidae																	
31. *Cardites laticostata* (G. B. Sowerby I, 1833)		55															3.44
32. *Cyclocardia beebei* (Hertlein, 1958)											5				50		3.44
33. *Strophocardia megastropha* (Gray, 1825)															10		0.625
Family Lucinidae																	
34. *Divalinga perparvula* (Dall, 1901)			30							10							2.5
35. *Lucina prolongata* (Carpenter, 1857)			10														0.625
36. *Lucinisca centrifuga* (Dall, 1901)			10	5			20			190	70	155	5				28.44
37. *Lucinisca fenestrata* (Hinds, 1845)												10					0.625
38. *Lucinoma annulatum* (Reeve, 1850)			5				5			10		40	10				4.375
39. *Neophysema aphanes* Taylor and Glover, 2005											45			50			5.93
40. *Parvilucina approximata* (Dall, 1901)		5	75	10						85		1815	5				124.69
41. *Parvilucina mazatlanica* (Carpenter, 1857)	35		5						10	125	520			25			45
42. *Pegophysema edentuloides* (Verrill, 1870)									5		5				5		0.94
43. *Radiolucina cancellaris* (Philippi, 1846)			295	5				15		70	350	295	10				65
Family Ungulinidae																	
44. *Diplodonta soror* (C. B. Adams, 1852)			15				5			10	5						2.19
45. *Diplodonta subquadrata* (Carpenter, 1856)	5										10						0.94
Family Thyasiridae																	
46. *Thyasira flexuosa* (Montagu, 1803)												40					2.5
Family Kellidae																	
47. *Kellia suborbicularis* (Montagu, 1803)														5			0.31
Family Chamidae																	
48. *Chama sordida* Broderip, 1835															15		094
Family Cardiidae																	
49. *Laevicardium elenense* (G. B. Sowerby II, 1841)			5														0.31
50. *Trachycardium belcheri* (Broderip and G. B. Sowerby I, 1829)	5		5														0.625
51. *Trachycardium procerum* (G B. Sowerby I, 1833)	5		5														0.625
52. *Trachycardium senticosum* (G. B. Sowerby I, 1833)			55														3.44
53. *Trigoniocardia granifera* (Broderip and G. B. Sowerby I, 1829)	5		85														5.63
54. *Trigoniocardia obovalis* (G. B. Sowerby I, 1833)	30		85				5				5						7.81
Family Veneridae																	
55. *Chione compta* (Broderip, 1835)		345									10	5					22.5
56. *Chione guatulcoensis* Hertlein and Strong, 1948	15	30	5							5							3.44
57. *Chionchione pulicaria* (Broderip, 1835)	30																1.875
58. *Cyclinella subquadrata* (Hanley, 1844)			5														0.31
59. *Dosinia dunkeri* (Philippi, 1844)			5														0.31
60. *Dosinia ponderosa* (Gray, 1838)			10				5										0.94
61. *Gouldia californica* Dall, 1917			460								60						32.5
62. *Lirophora kellettii* (Hinds, 1845)			10														0.625
63. *Lirophora mariae* (d'Orbigny, 1846)			5														0.31
64. *Megapitaria squalida* (G. B. Sowerby I, 1835)	5		460														29.06

Appendix 1. (continued)

Sampling station	52	24	47	35	23	48	26	51	34	18	22	30	33	50	25	29	
Type of substratum	MS	SS	MS	SS	SS	SC	SC	SC	SS	SS	SS	SC	SC	SC	SC	SC	Mean
Depth (m)	18	24	40	48	49	53	57	60	66	71	72	74	83	84	99	112	number of
Temperature (°C)	28	30	24	16	26	29	26	25.5	17	15	14.5	16	16	19	14.5	14.5	individuals
Dissolved oxygen (ml/l)	6.3	5.0	3.6	0.6	0.6	6.5	7.4	5.6	0.5	0.2	0.3	0.3	0.4	1.0	0.3	0.2	per m^2
65. *Periglypta multicostata* (G. B. Sowerby I, 1835)		5	5									5					0.94
66. *Pitar callicomatus* (Dall, 1902)			15			5											1.25
67. *Pitar concinnus* (G. B. Sowerby I, 1835)	60		10														4.375
68. *Pitar multispinosus* (G. B. Sowerby II, 1851)			5			5											0.625
69. *Transennella modesta* (G. B. Sowerby I, 1835)			20														1.25
Family Mactridae																	
70. *Mactrellona subalata* (Mörch, 1860)	10																0.625
71. *Mulinia pallida* (Broderip and G. B. Sowerby I, 1829)		10															0.625
Family Tellinidae																	
72. *Cymatoica undulata* (Hanley, 1844)			15	10			5			5	5						2.5
73. *Macoma elytrum* Keen, 1958			15				5										1.25
74. *Macoma siliqua* (C. B. Adams, 1852)										15	10	10					2.19
75. *Psammotreta aurora* (Hanley, 1844)			5														0.31
76. *Strigilla cicercula* (Philippi, 1846)		5	15														1.25
77. *Strigilla dichotoma* (Philippi, 1846)	55		5														0.31
78. *Strigilla interrupta* Mörch, 1860	30		110				5			5	5						9.69
79. *Strigilla* sp.			55														3.44
80. *Tellina carpenteri* Dall, 1900	30						5			10							2.81
81. *Tellina coani* Keen, 1971			200	10						20	5	5					15
82. *Tellina martinicensis* d'Orbigny, 1853			10							5		5					1.25
83. *Tellina pacifica* Dall, 1900			220														13.75
84. *Tellina pristiphora* Dall, 1900							10										0.625
Family Donacidae																	
85. *Donax gracilis* Hanley, 1845			75														4.69
Family Solecurtidae																	
86. *Tagelus politus* (Carpenter, 1857)			10														0.625
Family Semelidae																	
87. *Semele pallida* (G. B. Sowerby I, 1833)			15														0.94
88. *Semele verrucosa* Mörch, 1860			15														1.56
89. *Semelina campbellorum* Coan, 2003			285							5	60	90					27.5
Family Corbulidae																	
90. *Corbula ira* Dall, 1908															1210		75.625
91. *Corbula marmorata* Hinds, 1843			50														3.125
92. *Corbula nasuta* G. B. Sowerby I, 1833	25		2450	5	10			5			35	145					167.18
93. *Corbula ventricosa* A. Adams and Reeve, 1850				5								10	40				3.44
Family Pandoridae																	
94. *Pandora arcuata* G. B. Sowerby I, 1835	5							5									0.625
Family Verticordiidae																	
95. *Trigonulina novemcostatus* (A. Adams and Reeve, 1850)			25							5	10	55					5.94
Total individuals per station	97	134	2603	23	42	3	24	7	4	146	530	1117	24	17	414	11	
Total species per station	22	19	63	12	9	3	16	4	3	21	33	28	11	4	10	1	
Density (individuals/m^2) per station	485	670	13015	115	210	15	120	35	20	730	2650	5585	120	85	2070	55	